ROADBANK EROSION AND ITS CONTROL IN THE PIEDMONT UPLAND OF GEORGIA

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The Georgia Agricultural Experiment Stations
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ROADBANK EROSION AND ITS CONTROL IN THE PIEDMONT UPLAND OF GEORGIA

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INTRODUCTION

Erosion on unprotected roadbanks in the United States is recognized as a rapidly expanding problem, particularly in the Southeast. Few of the older roadbanks in this area have been stabilized and new construction of four-lane highways greatly increases erosion. When the Federal Interstate Road System is completed for the United States, approximately one million additional sediment-producing acres in adjacent roadside areas will be added to the present 16 million acres in the United States. This does not include the acreage in the State and county roads. Sediment production from many of these unprotected areas exceeds 300 tons of soil per acre annually. This eroded material is detrimental to highway maintenance, cultivated bottom lands, drainage systems, streams, and reservoirs.

In the hilly Piedmont Upland section of northwestern Georgia, deep cuts through ridges, made during highway construction, expose areas of raw infertile subsoils on roadbank slopes that are highly susceptible to erosion (fig. 1). Runoff and soil-loss measurements made at

Figure 1.--A common sight on unprotected road cuts throughout the United States, particularly in the Southeast.

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[1] Contribution from Soil and Water Conservation Research Division, Agricultural Research Service, USDA, in cooperation with the Soil Conservation Service, USDA, the Georgia Agricultural Experiment Station, the Georgia State Highway Department, and the Commissioner of Bartow County, Georgia.

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selected typical bare roadbanks in the project area have indicated that exceedingly high rates of erosion occur at these sites, owing to rapid runoff from high rates of rainfall. Also, frost is often a potent factor contributing to these soil losses, especially from steep, bare banks.

Roadbanks are difficult sites on which to establish protective plant covers, because both seeds and fertilizers are liable to be washed off. Stand maintenance is more of a problem on roadbanks than on farmlands, because roadbanks are subject to greater extremes of heat, drought, and cold.

An important part of the project's research included testing the capabilities of many cover species, soil treatments, and mulches for establishing and maintaining adequate protective cover on roadbanks at reasonable cost.

This project was started in November 1956 with field headquarters at Cartersville, Ga. Its principal objectives were (1) measuring soil and water losses from a series of typical bare roadbanks and (2) testing a wide range of vegetative and treatment methods to determine those most satisfactory for permanent roadbank protection.

METHODS AND PROCEDURES

Measurements of Runoff and Erosion

Six bare, cut roadbank sections were selected in 1957 for measurements of runoff and erosion; each section constituted a "runoff plot." They were located along State Highway 92, 10 to 15 miles south of Cartersville. One of the six plots graded toward Madison, one toward Lloyd, and four consisted of cuts through Cecil subsoil profiles. The plots were located in pairs on opposite sides of the highway, to provide a comparison of effects of northern and southern exposures. The three pairs of banks had slopes approximately 1:1 (1 foot horizontally to 1 foot vertically), 1.4:1, and 2.9:1, respectively. Plots 3 to 6 were located 5 miles north of plots 1 and 2, but at somewhat lower elevations. Annual rainfall was approximately 6 to 8 inches less at plots 5 and 6, and frost action was greatest at plots 1 and 2. Adjacent road ditch grades varied from 2.8 to 5.0 percent, each with a drop of 4 feet in elevation at lower ditch ends, which was sufficient for placement of equipment for measuring soil and water loss.

It was necessary to reslope two banks of the Cecil in order to form 1:1 side slopes. The runoff areas of the first four plots varied in size from 0.22 to 0.38 acre and originally included one-half of the paved highway adjacent to each plot in addition to the road shoulder, ditch, and bank slope. It was difficult to determine just what percentage of runoff occurred from the road pavement because of the variable effects of winds and automobile traffic. Therefore, a small vegetated earth ridge was formed on the road shoulder 2 feet from the edge of the pavement at each plot to divert pavement runoff. A similar small diversion ridge was placed above the crest of the roadbank cut at each plot to divert overwash from higher upslope areas. Heights of the roadbank cuts ranged from 2.5 feet at the lower end to 16 feet at the highest points, with lengths of 206 to 365 feet.

The total individual runoff areas for the six plots after the diversion ridges were constructed vary from 0.16 to 0.30 acre. The roadbank shoulders are now well vegetated to the upper side of the flow channel, reducing the actual erodible areas (including the channels and banks) from 0.11 to 0.21 acre.

Six flumes, N-2 type Weir Coshocton soil and water samplers, and storage tank assemblies were designed and fabricated. When completed, these measuring and sampling units, each with masonry head, wing wall, and a 54-cu. ft. storage tank, were installed at the lower ends of the flow channels of each plot.

All runoff with soil suspension flowed through the 1-foot deep H-flume onto the Coshocton vane sampler. A 0.5-percent sample of the runoff was diverted to the storage tank located below the sampler (figs. 2, 3, and 4). A standard water-stage recorder with a stilling well was attached to the side of the flume and also was used to measure rate and volume of runoff. A nearby recording rain gage measured the amount and intensity of the rainfall at each set of plots.

Figure 2.--View of a soil and water measuring device installed at the lower end of a plot ditch for measurement of losses occurring from highway cut slopes. The bare road cut and ditch are shown in the background where the white papers appear.

Figure 3.--An overall view of a soil and water measuring device in the lower end of the plot ditch. The black, covered, 54-cubic-foot storage tank is in the background where the 0.5-percent sample is collected.

Figure 4.--Soil and water from the runoff plot has passed through the H-flume and is pouring onto the rotary Coshocton wheel, which is taking a sample of 0.5-percent of the runoff with suspended load. This fraction is diverted to the 54-cubic-foot storage tank below the measuring device.

Three representative 1-qt. samples of runoff with soil suspension were collected from the storage tank after each storm. These were used for calculating the plot soil losses per acre. Runoff and soil losses were calculated from the 0.5-percent sample collected in the tank. The water-stage recorder data also provided an additional means for computing runoff and are now considered the more dependable method. Heavy deposits of coarse soil material settled in the flumes after some heavy rains; therefore, after these rains, all deposits from the flumes were sampled separately, weighed, and the amounts added to the quantity of eroded soil in the tanks for determining total plot soil losses per acre.

Highway ditch grades varied considerably, which resulted in either erosion or deposition in the flow channel. To measure these dimension and capacity changes, two rows of metal hub stakes, 3/8 inch in diameter, were spaced 6 by 6 feet in each flow channel and one additional row was placed in the toe of the bank 18 inches from the inner row of ditch stakes (fig. 5). with their tops well above ditch level. Measurements were made with a specially designed horizontal bar and rod device at 1-foot intervals across the diagonals at the time of installation and annually thereafter. These depth measurements were used for calculating deposition or erosion in the flow channel (figs. 6 and 7). Soil deposition calculated from these measurements was added to the soil losses as computed from the two soil samples collected by measuring devices at the plot outlet, to determine the total amounts eroded from the unprotected roadbanks.[3]

In 1957 metal pins spaced 4 feet apart in two parallel rows were driven into one pair of banks until the tops were flush with the soil surface for observational purposes. On May 20, 1958, two rows of pins were installed similarly in each of the other four banks. Later it was decided to measure the exposed pin heights annually to determine and compare the bank erosion with the combined losses as measured by the previously described methods. It was found that

[3] Only trivial amounts, produced by ditch scour, were included in plot outlet losses.

Figure 5.--Two rows of metal hub stakes spoced 6 by 6 feet are shown in the flow chonnel of o runoff plot. Annuol meosurements ore made ot 1-foot intervals oround the squares of stokes and ocross the diagonols with equipment especially designed to determine the soil deposition or erosion that moy have occurred in the flow chonnel.

Figure 6.--The specially designed surveying equipment is being used in connection with metal hub stakes for measurement of erosion or sedimentation in the flow chonnel.

Figure 7.--Soil deposits were 8 inches deep in the upper end of the flow channel, as shown in the foreground of this photograph. The rilled effect of the bank surface was caused by runoff during one rain that followed severe frost action. Later, all the loose soil was washed from the bank, leaving it relatively smooth and firm.

an insufficient number of pins were present in the irregular bank surfaces for accurate determination of the rate of erosion. Consequently, three additional rows of pins were placed in each of the six banks in the early spring of 1960.

Tests of Plant Species, Mulches, and Fertility Practices

From September 1956 to April 1960, 40 planting sites were established on bare roadbanks for the vegetative studies. These planting sites were scattered at random over the project area within a 25-mile radius of Cartersville with the exception of two located adjacent to the runoff plots. Quantitative soil loss measurements by pin method were made only on the two vegetated sites adjacent to runoff plots 1 and 2. The sites for vegetative studies comprised a large number of bank sections or individual plots, with 28 different varieties and species planted with and without mulch on diverse soil types, degrees of slope, and directions of exposure. Included were cool-and warm-season grasses and legumes, vines for steep areas, and ornamentals near public areas.

Roadbank plots for the vegetative study were laid out perpendicular to the road surface. They usually varied in width and extended from the road drainage ditches to the tops of the banks. Plots in the plant adaptation study were from 20 to 40 feet wide and were subdivided into plots 10 to 20 feet wide in order to test the effects of mulch and no mulch under different soil and slope conditions.

Three rapidly developing warm-season grasses--common Bermuda (a spreading grass), lovegrass, and Wilmington Bahia (bunchgrasses)--and one slowly developing cool-season legume--crownvetch--were the four species planted and treated with different mulch materials. Coastal bermudagrass, kudzu, honeysuckle, English ivy, vinca minor, daylilies, iris, jasmine, procumbine lespedeza, and crownvetch were set out and spaced 3 by 3 feet, to develop cover on roadside area. Seeding rates and mulch materials used in the studies are shown in tables 1, 2, and 3.

A uniform fertilizer treatment of 2,000 pounds of 4-12-12 plus 2 tons of lime per acre was made at seeding and planting time. If possible, these materials were worked into the soil with

TABLE 1.--Species and seeding rates used to develop cover on roadside areas

Species	Rate of seeding	Species	Rate of seeding
	lb./acre		lb./acre
Tall fescue	30	Wilmington bahiagrass	40
Orchardgrass	30	Argentine bahiagrass	40
Bromegrass	30	Common bermudagrass	30
Ryegrass (as nursecrop and to grow mulch in place)	30	Northrup King bermudagrass 37	30
Abruzzi rye (as nursecrop and to grow mulch in place)	60	Weeping lovegrass	30
Crownvetch	20	Kobe lespedeza	30
Hairy vetch)	30	Sericea lespedeza	40
Grandiflora vetch)	5	Brown top millet (to grow mulch in place)	40
Pensacola bahiagrass	40	Broomsedge	Light mulch when seed were mature

TABLE 2.--Mulches used on seeded grasses and rate of application

Species, soils, and dates of seeding	Replications	Mulch treatments
	Number	
Common Bermuda, seeded on Cecil soil, 1958, 1959, 1960	10 (total)	Pine straw, 1 to 2 tons per acre. acre. Grain straw, 2 tons/acre. Grain straw, 4 tons/acre. Yellow plastic. Clear plastic. White plastic. Fine jute, 1/2- by 1/2-inch mesh. Coarse jute, 2- by 2-inch mesh. No mulch.
Weeping lovegrass, seeded on Fullerton soil, April 1958	5	No mulch. Grain straw, 2 tons/acre. Grain straw, 4 tons/acre. Paper Paper mulch, 1/2- by 1-inch mesh. Grass mat, very thin material with seed attached.
Wilmington Bahia, seeded April 1957		No mulch. Pine straw, 1 to 2 tons per acre. Paper mulch, 1/2- by 1-inch mesh. Sericea straw, 1 to 2 tons per acre.
On Cecil soil	3	
On Decatur soil	2	

a chain harrow. But on banks with slopes greater than 2:1 the loosened soil, mixed together with fertilizer and lime, rolled to the bottom of the bank. Also, trees and fences at the tops of some banks prevented soil preparation with the tractor and chain harrow. On these, hand hoes and rakes were used to scarify slightly the bank surfaces.

The optimum seeding periods, at best, were short. Cool-season plants seeded between September 1 and November 1 usually came up quickly; whereas, when planted after November 1, the seed frequently lay in the ground until spring before germinating. Warm-season species seeded from April 1 to June 15 usually came up to good stands quickly. Late plantings were not so successful as the early plantings because of inadequate moisture.

TABLE 3.--Mulches used on crownvetch seeded on Cecil soil

Date seeded	Replications	Mulch treatments
	Number	
October 1958 ... March 1959 ...	2 ... 2 ...	Pine straw, 1 to 2 tons/acre. Grain straw, 2 tons/acre. Grain straw, 4 tons/acre. Sawdust, 1/2 to 1 inch deep. White and clear plastic. No mulch.
September 1959 ...	2 ...	Pine straw, 1 to 2 tons/acre. Grain straw, 2 tons/acre. Grain straw, 4 tons/acre. Sawdust, 1/2 to 1 inch deep. White plastic. Fine jute, 1/2-by 1/2-inch mesh. Coarse jute, 2- by 2-inch mesh. No mulch.
March 1960 ...	2 ...	Pine straw, 1 to 2 tons/acre. Grain straw, 2 tons/acre. Grain straw, 4 tons acre. Sawdust, 1/2 to 1 inch deep. White plastic. Jute, 2- by 2-inch mesh. Water-soluble latex, 100 gal. stock solution diluted with 700 gal. water. No mulch.

Nitrogen Evaluation Tests on Bermudagrass

The nitrogen evaluation study was located on a relatively flat area. After disking, plots 6 by 20 feet were staked out, different rates of 8-24-8 fertilizer containing either water-soluble or slowly water-soluble nitrogen, and 2 tons of lime were applied by hand and the soil surface smoothed by handraking. This smoothing process mixed fertilizer and lime with the soil and left a good planting surface on which bermudagrass seed were broadcast and covered by hand raking.

Four replications of treatments were laid out in a randomized manner. Treatments 1, 2, 3, and 4 were fertilized with 625, 1,250, 1,875, and 2,500 pounds per acre of 8-24-8 containing slowly water-soluble nitrogen. Treatments 5, 6, and 7 were fertilized with 625, 1,250, and 1,875 pounds per acre, respectively, of 8-24-8 containing water-soluble nitrogen. Treatments 8, 9, 10, and 11 were all fertilized initially with 625 pounds per acre of 8-24-8 containing water-soluble nitrogen. In treatments 1 through 7, all the fertilizers were applied at the beginning of the experiment, whereas in treatments 8 through 11, nitrogen was applied as a topdressing at the rate of 50 pounds per acre, as needed, to keep the Bermuda healthy and provide adequate cover. Four sources of nitrogen were used for topdressing ammonium nitrate, urea, urea-form, and 10-20-10. Urea-form reacted as a slowly water-soluble form of nitrogen; the 10-20-10 contained slowly water-soluble nitrogen, and ammonium nitrate and urea were water-soluble. All the 8-24-8 and 10-20-10 fertilizer was ready mixed when received at the project.

Yields were obtained by clipping a lengthwise swath through the middle of each plot, green weight was taken, a moisture sample collected and oven-dried, and yields reported in dry weight per acre. Two clippings were made in 1959, one in early July and the second in late October. Results were tabulated and averaged for the year 1959.

EXPERIMENTAL RESULTS

Runoff and Erosion

Precipitation in the Southeast is characterized by occasional storms of high intensities and short durations. These produced excessive runoff and soil losses on most of the unprotected steep roadbank cuts. Thus far, the measured precipitation where these experiments are located has varied from 40 to 50 inches annually, depending upon the exact location of the gaging station. Intermittent frost action from December through February and occasionally in March caused heavy soil losses on non-vegetated cut roadbanks. On steep banks the loose soil rolled down the slope upon thawing, and was easily washed from the banks when runoff occurred.

Results for 1957

During 1957 data for 6 months (July 1-December 31) were collected from four of the bare roadbank plots. Due to the time required to construct the installations, plots 5 and 6 were not put into operation until January 1, 1958. The 6 months' data for plots 1, 2, 3, and 4 are shown in table 4. Even though runoff and erosion losses were high during this period, frost action was not a factor because the soil that had been loosened by freezing during the previous winter had been eroded from the bank prior to installation of measuring equipment and flow channels contained no deposited soil. Roadbank orientation was not a major factor in relation to erosion losses during the 6-month measuring period. Of the 25 rains occurring at plots 1 and 2, only 21 produced runoff and erosion. Twenty-three rains occurred at plots 3 and 4, but only 20 produced runoff and erosion.

TABLE 4.--Runoff and erosion from bare roadside cuts and flow channels of bare Cecil clay subsoil, Cartersville, Ga., July 1, 1957, to December 31, 1957[1]

No.	Plot description: Area, slope, height, and length	Rainfall			Outlet	Channel deposition	Total area
		Total	Rains	Runoff			
		Inches	Number	Inches	Tons/acre	Tons/acre	Tons/acre
1.	Runoff area, 0.16 acre; erodible area, 0.11 acre. Bank slope 1.4:1, faces N.70°W. Bank height 5 to 16 feet; length, 206 feet.	20.9	25	4.3	13.0	[3]	13.0
2.	Runoff area, 0.27 acre; erodible area, 0.21 acre. Bank slope 1.25:1, faces S.70°E. Bank height 5 to 14 feet; length, 255 feet.	20.9	25	2.4	24.0	[2]	24.0
3.	Runoff area, 0.21 acre; erodible area, 0.14 acre. Bank slope 2.5:1, faces N.70°W. Bank height 2 to 10 feet; length, 365 feet.	20.6	23	7.0	80.5	[3]	80.5
4.	Runoff area, 0.30 acre; erodible 0.20 acre. Bank slope 3.3:1, faces S.70°E. Bank height 2 to 12 feet; length, 310 feet.	20.6	23	3.6	17.6	[3]	17.6

[1] Air-dry weight of soil deposited in the channel was 72 pounds per cubic foot.
[2] Nil.
[3] Slight erosion from the channels indicated by hub-stake calculations was included in the plot losses measured at the plot outlet.

Erosion occurred in the ditch channels of plots 3 and 4, owing to respective grades of 5 and 3.8 percent, with greater erosion occurring in steeper plot 3.

Results for 1958

Annual erosion losses for 1958 were high, particularly on the first four plots, because frost action was a major factor from December 1957 to February 1958 (figs. 8 and 9). The soil was

Figure 8.--The canes af laase soil are the result af freezing and thawing on a 1:1 Cecil clay unprotected roadbank facing narth. The laase sail rolled dawn the bank inta the ditch in a 2-day periad after thawing.

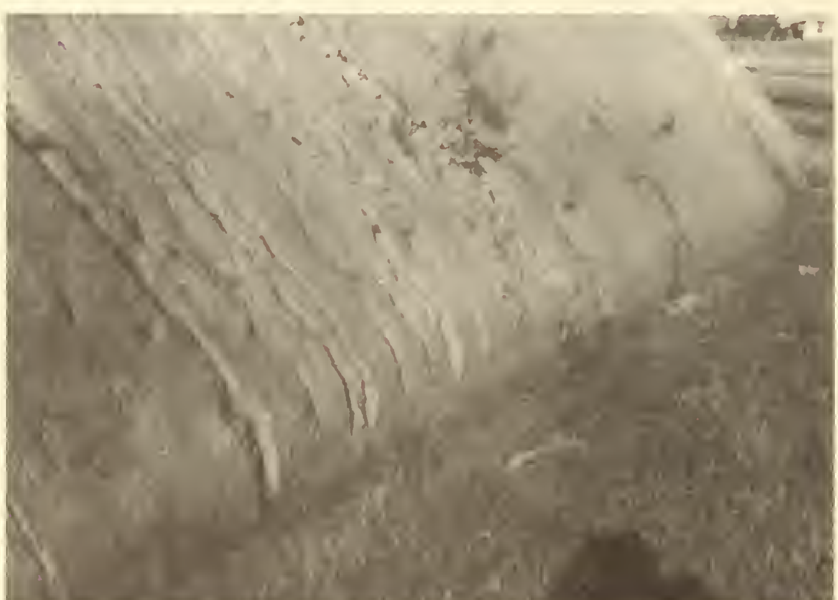

Figure 9.--This is the oppasite bank facing the south just across a small road from the bank in figure 8. The bank in this figure had dried aut and na freezing ar erasian from frost actian had accurred.

frozen and heaved up on the banks from 1/4 to 1 inch during the various freezes. Upon thawing, the loose soil was easily washed from the banks when runoff occurred.

Annual precipitation was 49.6 inches at plots 1 and 2 and included 51 storms (table 5). However, only 25 of the storms produced runoff and erosion. Soil losses for plot 2, facing southeast, were less than half of plot 1, with a northern exposure. Soil losses on plot 1 ranged from 0.03 to 3.2 tons per acre per erosion-producing rain, whereas losses from plot 2 ranged from 0.04 to 4.4 tons per acre per rain.

The two rows of observational metal pins, installed with their tops flush with the surface in the banks of plots 1 and 2 on May 9, 1957, were measured in December 1958 after 19 months of exposure. The soil had eroded until the pin tops were from 0 to 0.29 feet above the soil surface (fig. 10). The average exposure of pin tops over the entire bank was 0.1 foot. Calculation of soil losses from the pin exposure gave an annual loss of 156.8 tons per acre for each plot, exclusive of soil deposition in the flow channel and the 18-inch-wide strip just above the channel at the toe of the bank. A weight of 72 pounds per cubic foot was used for calculating the amount of soil deposited in the flow channel. The losses calculated by the standard procedure were 359.4 tons for plot 1 and 120.1 tons for plot 2. Therefore, it was concluded that an insufficient number of pins was in the irregularly rilled bank to determine accurately the losses by bank pin exposure measurements. Consequently, in the early spring of 1960, three additional rows of pins were installed in each bank.

Two rows of metal pins had also been similarly installed on the extended bank section just north of the upper ends of the bare plots 1 and 2 on May 9, 1957. These vegetated plots are

TABLE 5.--Runoff and erosion from bare roadside cuts and flow channels, Cartersville, Ga., January 1, 1958, to December 31, 1958

No.	Plot description: Area, slope, height, and length	Rainfall			Outlet	Channel deposition	Total area
		Total	Rains	Runoff			
		Inches	Number	Inches	Tons/acre	Tons/acre	Tons/acre
1.	Runoff area, 0.16 acre; erodible area, 0.11 acre. Bank slope, 1.4:1; faces N.70°W. Bank height, 5 to 16 feet; length, 206 feet.	49.6	51	5.6	30.0	329.4	359.4
2.	Runoff area, 0.27 acre; erodible area, 0.21 acre. Bank slope, 1.25:1; faces S.70°E. Bank height, 5 to 14 feet; length, 255 feet.	49.6	51	6.2	27.3	92.8	120.1
3.	Runoff area, 0.21 acre; erodible area, 0.14 acre. Bank slope, 2.5:1; faces N.70°W. Bank height, 2 to 10 feet; length, 365 feet.	41.7	49	7.9	103.5	([3])	103.5
4.	Runoff area, 0.30 acre; erodible area, 0.20 acre. Bank slope, 3.3:1; faces S.70°E. Bank height, 2 to 12 feet; length, 310 feet.	41.7	49	3.7	45.2	([3])	45.2
5.	Runoff area, 0.18 acre; erodible area, 0.12 acre. Bank slope, 1:1; faces N.70°W. Bank height, 4 to 15 feet; length, 296 feet.	41.7	49	3.9	25.7	([3])	[4] 25.7
6.	Runoff area, 0.23 acre; erodible area, 0.15 acre. Bank slope 1.1:1; faces S.70°E. Bank height, 5 to 15 feet; length, 321 feet.	41.7	49	3.9	24.5	([3])	[4] 24.5

[1] Soil losses from the bare bank and channel calculated from outlet measurements. Erosion from the channel indicated by hub stake calculations was included in outlet totals.

[2] Soil losses from the bare bank and channel calculated from the lower 3 rows of metal hub stakes. Air-dry weight of soil deposited in the channel averaged 72 pounds per cubic foot.

[3] Erosion.

[4] Plots 5 and 6 were new, firm banks.

Figure 10.--A part of the two rows of metal pins driven into the bare bank until the tops were flush with the soil surface when the plots were established. After 2 years of erosion the pin tops are from 0.02 to 0.35 foot above the soil surface. The soil loosened by frost action has been washed from the upper part of the bank leaving it relatively firm.

separated from the runoff plots by a metal barrier at the crest of the areas so that no runoff from the plots with vegetation enters the measured areas of plots 1 and 2.

Three vegetated sections were seeded to lovegrass, bermudagrass, and Argentine bahiagrass. A similar bank extension just north of plot 2 was seeded to a 40-foot section of weeping lovegrass and a 40-foot strip of common bermudagrass. The pins were extremely difficult to locate in 1959 because they had been covered with vegetation since shortly after the plots were planted. They were still flush with the soil surface, and no soil deposits were visible in the flow channels, which indicated that no appreciable erosion had occurred on these sections.

Annual precipitation at runoff plots 3 and 4 during 1958 was 41.7 inches, including 49 storms. Runoff and erosion were produced by 26 of the storms on plot 3 and 27 on plot 4. Soil losses from plot 3, with a roadbank slope of 2.5:1 and northwest exposure, were 103.5 tons per acre in 1958 and from plot 4, with a roadbank slope of 3.3:1 and facing southeast, 45.2 tons per acre. Erosion on plots 3 and 4 ranged from 0.01 to 11.5 tons per acre per erosion-producing rain. Some of the soil loosened by frost action settled back in place upon thawing and did not roll down the bank on these relatively gentle slopes. However, more than twice as much soil was lost from the bank facing the northwest as from the one facing southeast (fig. 11). On May 20, 1958, metal hub stakes were installed in the flow channels and two rows of metal pins were installed on the banks of each plot, as had been done on plots 1 and 2. Measurements of the stakes spaced 6 by 6 feet in the flow channel and in rows 18 inches up the bank, made in late December 1958, revealed that the increased exposure averaged 0.02 foot. Calculation showed slight erosion, instead of deposition, in each channel amounting to 7.9 tons per acre on plot 3 and 4.8 tons on plot 4. This erosion in the channels was also included in the washoff as measured by the Coshocton sampler.

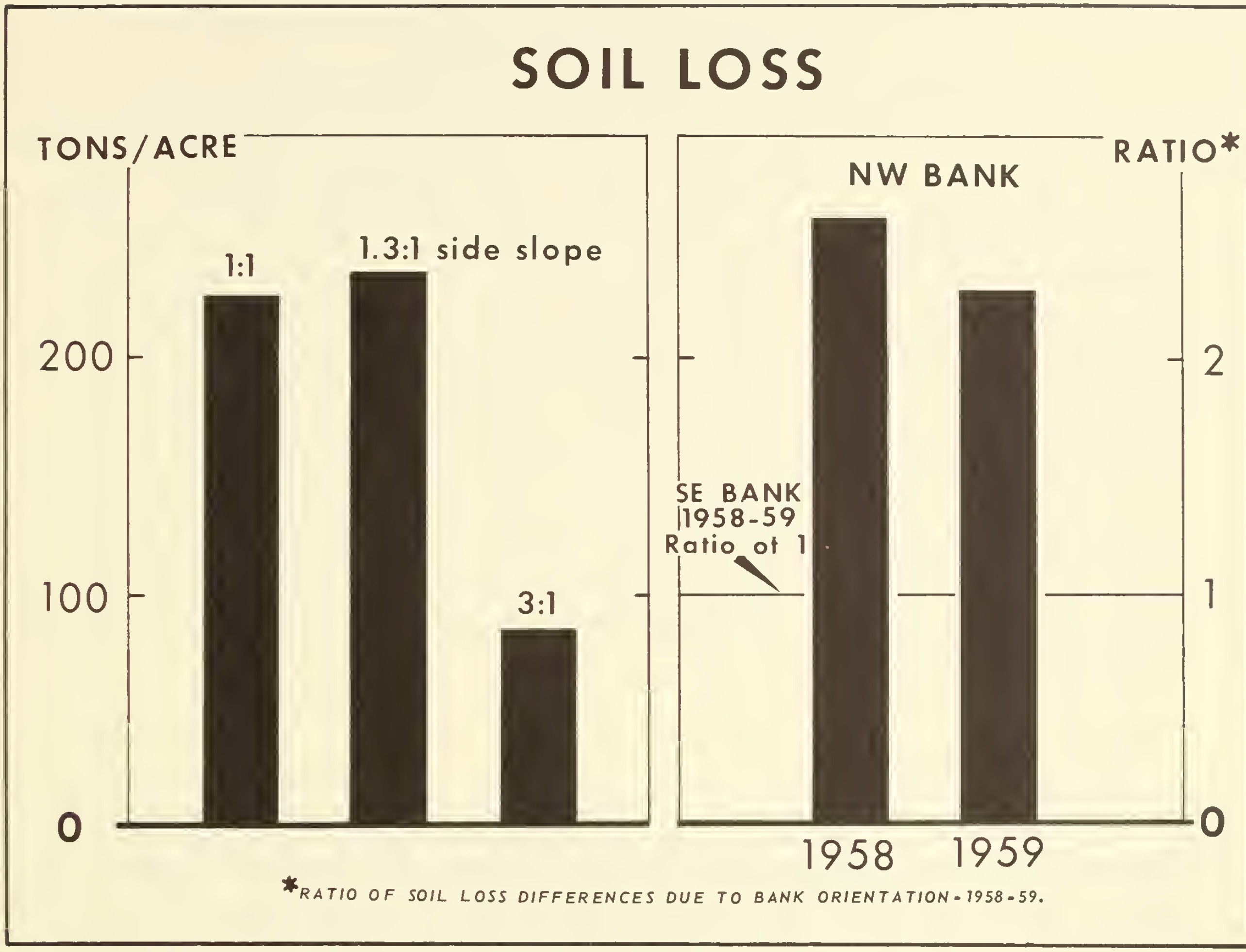

Figure 11.--Soil losses from different bore roodbank side slopes ond the rotio of soil losses due to bonk orientotion, 1956, Corterville, Go.

Companion plots 5 and 6 were resloped to form a 1:1 side slope in December 1957 and put into operation on January 1, 1958. Only 29 of the 49 storms on plots 5 and 6 produced runoff and erosion. Soil losses on plot 5, which faces the northwest, varied from 0.01 to 2.82 tons per acre per rain; whereas, losses from plot 6, which faces the southeast, varied from 0.03 to 6.07 tons per acre per rain. On December 30, 1958, measurement of exposure shown by metal hub stakes spaced 6 by 6 feet in the flow channel showed the exposure to average 0.01 foot, indicating slight erosion in each channel for a distance of 100 feet above the measuring devices. No appreciable frost action occurred on these banks. This was attributed to minimum infiltration on the two newly cut, firm, steep banks. Only slight pin exposure was visible on the bank; consequently, no measurements of these pins were made in 1958.

Results for 1959

Annual runoff and erosion losses for 1959 are reported in table 6. Eighteen more storms occurred in 1959 than in 1958 with 5.1 inches less precipitation. Twenty-three of the storms

TABLE 6.--Runoff and erosion from bare roadside cuts and flow channels, Cartersville, Ga., January 1, 1959, to December 31, 1959

No.	Plot description: Area, slope, height, and length	Rainfall			Outlet[1]	Channel deposition[2]	Total area
		Total	Rains	Runoff			
		Inches	Number	Inches	Tons/acre	Tons/acre	Tons/acre
1.	Runoff area, 0.16 acre; erodible area, 0.11 acre. Bank slope, 1.4:1; faces N.70°W. Bank height, 5 to 16 feet; length, 206 feet.	44.5	69	3.3	12.6	315.6	328.2
2.	Runoff area, 0.27 acre; erodible area, 0.21 acre. Bank slope, 1.25:1; faces S.70°E. Bank height, 5 to 14 feet; length, 255 feet.	44.5	69	5.8	25.6	117.7	143.3
3.	Runoff area, 0.21 acre; erodible area, 0.14 acre. Bank slope, 2.5:1; faces N.70°W. Bank height, 2 to 10 feet; length, 365 feet.	40.1	66	7.6	126.0	([3])	126.0
4.	Runoff area, 0.30 acre; erodible area, 0.20 acre. Bank slope, 3.3:1; faces S.70°E. Bank height, 2 to 12 feet; length, 310 feet.	40.1	66	4.9	41.2	([3])	41.2
5.	Runoff area, 0.18 acre; erodible area, 0.12 acre. Bank slope, 1:1; faces N.70°W. Bank height, 4 to 15 feet; length, 296 feet.	40.1	66	5.4	53.2	250.0	303.3
6.	Runoff area, 0.23 acre; erodible area, 0.15 acre. Bank slope 1.1:1; faces S.70°E. Bank height, 5 to 15 feet; length, 321 feet.	40.1	66	3.6	22.8	122.7	145.5

[1] Soil losses from the bare bank and channel calculated from outlet measuring device data. Air-dry weight of soil deposited in the channel averaged 72 pounds per cubic foot. Erosion from the channel indicated by hub stake calculations was accounted for by the measuring device.
[2] Soil losses from the bare bank and channel calculated from the lower 3 rows of metal hub stakes.
[3] Erosion.

produced runoff on plot 1, and 27 on plot 2. The erosion-producing storms ranged from 0.40 to 3.95 inches per rain, with durations of 1 to 26 hours. Some non-erosive storms amounted to 0.90 inch per rain, with a duration of 5 hours. Runoff ranged from 1.6 to 28.6 percent on plot 1, and from 0.1 to 32.2 percent on plot 2. Soil losses on plot 1 ranged from 0.01 to 3.74 tons per acre per rain; losses for plot 2 varied from 0.02 to 4.47 tons per acre per rain. Channel deposition had increased in both plots until it was about 8 inches deep at the upper ends of the channel. Originally the channels were U-shaped, but were almost flat across the entire 6-foot ditch width in 1959 and the low points of the channels were at their margins adjacent to the vegetated road shoulders. As a result of deposition in the upper end of the channels, the grades were almost uniform for the entire length of the two ditches (fig. 7). This heavy deposition was caused primarily by frost action both years from about December 15 to February 15. Insufficient volume of runoff water and low velocity prevented self-cleaning, as the grade had been decreased at the upper end of the channel. It is anticipated that deposition in the upper end of the channel will not be as great in the future because the grade has been increased by deposition made in the past.

The two rows of observational metal bank pins installed in each plot May 9, 1957, were measured again in late December 1959. The pin top exposures ranged from 0.02 to 0.35 foot per pin, with averages of 0.19 foot on plot 1 and 0.15 foot on plot 2.

On January 1, 1960, the two rows of metal pins in the separately vegetated plots to the north of runoff plots 1 and 2 were still flush with the soil surface, indicating there had been no erosion from these protected roadbank sections.

Total annual 1959 precipitation at these two plots was 40.1 inches, including 66 storms. Only 26 of the 66 storms produced runoff and erosion on plot 3; 27 storms on plot 4. The erosion-producing rains varied from 0.35 to 3.30 inches were durations of 0.25 to 26.0 hours. The maximum storm that did not produce runoff was 0.95 inch, with a duration of 12 hours. Runoff varied from 4.4 to 81.6 percent on plot 3; 0.36 to 68 percent on plot 4. Soil losses on plot 3 ranged from 0.42 to 16.4 tons per acre per rain, and on plot 4 from 0.03 to 11.8. Erosion rather than deposition occurred in the channels of both plots. Considerable bank erosion as a result of frost action was noted on both plots.

Measurements at stake locations in the flow channels revealed that considerable erosion occurred in the channels and on the sides of the channels in both plots. Bank pin exposure on plot 3 varied from 0.04 to 0.41 foot, with an average of 0.15 foot above the soil surface. On plot 4 the pin exposure varied from 0.00 to 0.24 foot, with an average exposure of 0.08 foot above the surface. The density of the soil in the firm banks has not been determined. The bank on each plot is badly rilled; consequently, three additional rows of pins were installed during March 1960 in order to determine more accurately the soil losses from pin exposure measurements.

Only 27 of the 66 storms on plots 5 and 6 produced runoff. The erosion-producing storms varied from 0.4 to 3.3 inches with durations of 0.30 to 26.0 hours. The maximum storm that did not produce runoff was 0.95 inches, which occurred over a 3-hour period. Runoff varied from 0.33 to 65 percent on the two plots. Soil losses from plot 5 in 1959 varied from 0.07 to 9.0 tons per acre per rain; losses from plot 6 varied from 0.01 to 3.03 tons per acre per rain.

The annual soil loss for plot 5 was 303.3 tons per acre; that for plot 6 was 145.5 tons per acre. Considerable deposition occurred in both channels in 1959 as contrasted with erosion occurring in 1958. Frost action and pin exposure averaging 0.16 foot on plot 5, and 0.09 foot on plot 6.

Seasonal Erosion

Monthly losses from the six roadbank plots for 1959 include only the amount of sediment collected through the outlet measuring devices (fig. 12). Seasonal losses from highway roadbanks may not coincide with the seasonal losses from cultivated farmland areas and may not follow a uniform seasonal pattern (fig. 12). This may be explained by the fact that cultivated fields are vulnerable to erosion during the spring and early summer from land preparation and tillage.

The unprotected roadbanks are never plowed but are placed in a seasonably erodible condition by annual frost action occurring, thus far, from about the middle of December to the middle of February at Cartersville. Alternate freezing and thawing generally loosens the soil to a combined annual depth of 1 to 2 inches. Upon thawing, a part of the loosened soil rolls down the bank by gravity, especially on 1.5 to 1, or steeper side, slopes. The rate at which the remaining loose soil is moved from the banks and flow channels depends upon the rate and volume of runoff as affected by the rainfall pattern; the amount, duration, and intensity of storms. The soil is more easily moved from the banks than from the flow channels. Once deposited in the channel, it is much harder to move from the channel because of partial solidification and insufficient volume of water for runoff. Once the loose soil has been moved, the banks become relatively compact and dense. Heavy losses from the banks do not often occur again until after the following year's frost action. Observation indicates that the majority of the soil washed from the banks is a thin film of loosened soil that is a result of wetting and drying--sometimes called slaking. Raindrop impact or splash erosion occurs on all the bare banks and particularly on the northwest-facing banks.

The heaviest seasonal losses, exclusive of channel deposition, for 1958-59 are listed below:

Plots--	Months the highest soil losses occurred in-- 1958	1959
1 and 2	May, June, and July	May, July, and October.
3 and 4	April, July, and October	March, April, May, and October.
5 and 6	do	May, July, and October.

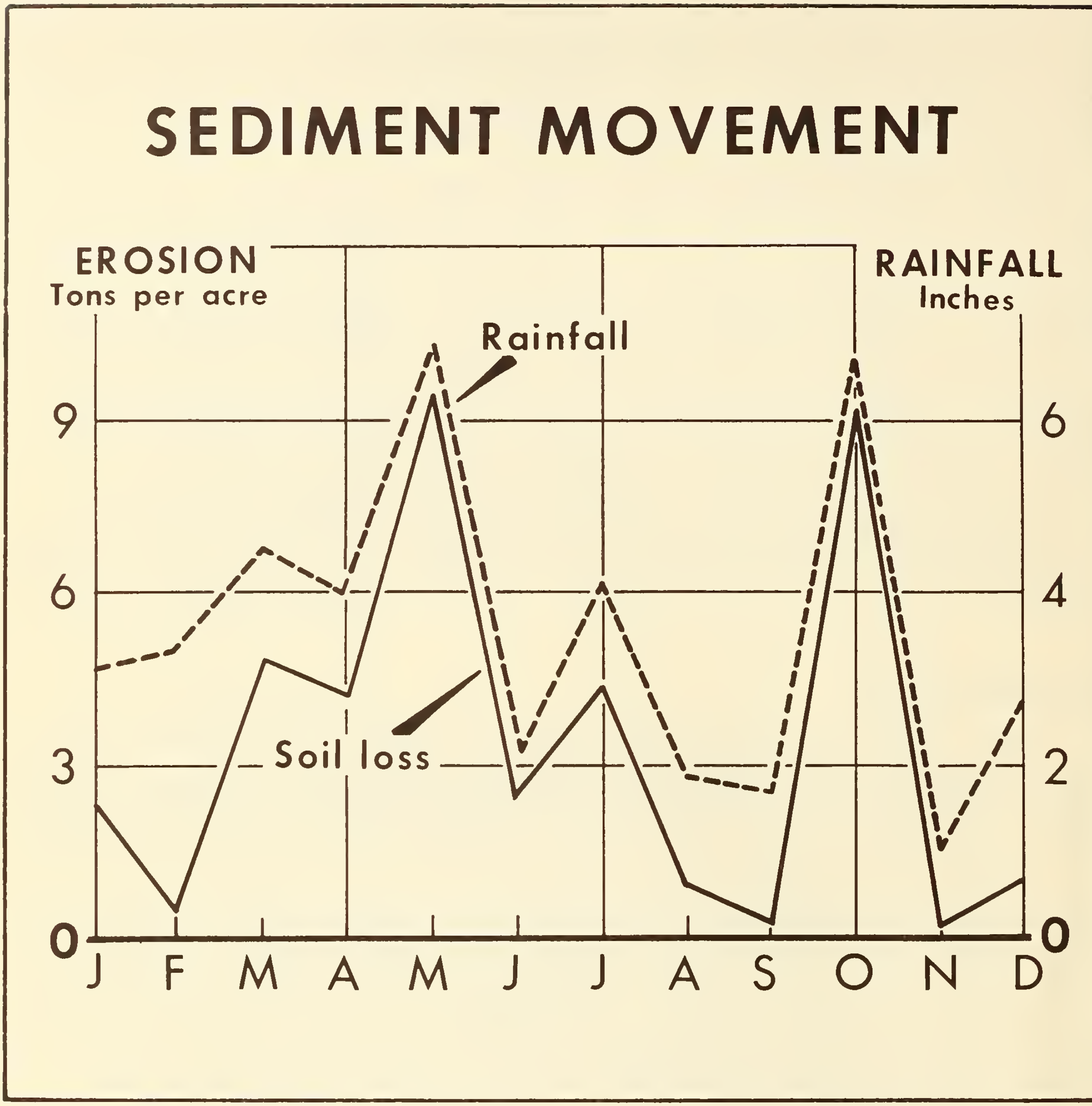

Figure 12.--Average monthly roinfoll ond soil movement from six plots os measured ot chonnel outlets, in 1959, Carterville, Ga.

Exposure or Orientation

Roadbank orientation, or the direction the bare banks face, was a major factor in the erosion losses occurring on the six roadbank erosion plots (figs. 8 and 9). This was due to two reasons. First, it is known definitely that frost action contributes a major influence. Banks with a north to northwest aspect received less solar radiation and were more readily frozen than those facing east or southeast, and stayed frozen longer. Second, the bulk of precipitation in this area comes from a westerly direction; consequently, a bank facing west will receive a greater amount of raindrop impact than one facing in an easterly direction. During torrential storms, raindrop impact and splash on the bare, unprotected soil surfaces loosen great quantities of soil and place it in suspension. Once in suspension, it is easily eroded from the banks by the runoff waters.

Slope of bank has a marked effect upon erosion (fig. 8). Soil loosened by frost action does not roll down the 3:1 slope bank upon thawing, but remains in place unless runoff washes the loose soil from the banks. Runoff is probably also less on the gentler slopes because of better opportunity for infiltration than on the steep slopes.

Efficiency of Measuring Equipment

Runoff and erosion measuring devices installed at plot outlets were generally satisfactory, except that undesirable deposition of heavy sediment in the approach flumes remained a problem. False or sloping floors in the flume bottoms at right angles to the line of flow with a rise of 1 inch to 8 inches appeared to reduce sediment in the flumes at low flows with small suspension loads. The inner flume floor was covered with silt when heavy runoff and heavy suspension loads occurred, particularly when rainfall and runoff ceased abruptly.

Flume lengths did not affect the amounts of sedimentation. A 62-inch length flume had just as much sediment per unit area as did a 37-inch flume.

Metal hub stakes in the flow channels were satisfactory for determining sedimentation or erosion in the flow channels if a sufficient number of pins were present. But only two rows of metal pins spaced 4 feet apart in rows were not sufficient for measuring erosion from the bare roadbanks. Observation of metal pins in well-established vegetated banks showed that no erosion occurred.

Roadbank Covers

Cool-Season Species

Plantings of fescue, orchard, and Oklahoma brome (all cool-season grasses) performed well. When planted during the optimum fall period and with favorable moisture conditions, good stands and cover developed by the next spring. All these grasses remained green throughout the year except during severe summer droughts or extremely low winter temperatures. Fescue was more vigorous and disease-resistant than orchard or brome.

Of all the fall-planted annuals, Abruzzi rye produced the quickest cover. When seeded at the most favorable period and at the rate of 60 pounds per acre, good cover developed in 4 to 6 weeks after planting. After maturity the straw provided good mulch grown in place, which lasted for a period of 2 or more years. Some excellent stands of such permanent species as crownvetch were obtained by seeding with rye or in rye straw grown in place without cultural treatment (fig. 13).

Annual ryegrass provided excellent cover the first year of seeding, but its thick growth was so competitive that it was impossible to grow other plants with it. The residue decayed rapidly and disappeared in 1 year's time.

Crownvetch, a promising cool-season perennial legume, was propagated by seed and plants. It was planted from September to April, inclusive. Cover was quickly developed by seeding on a prepared seedbed in combination with 60 pounds of Abruzzi rye, or by mulching with crop straws after fertilizing and seeding. Fall transplantings at the base of steep banks were covered with frost-loosened material and often killed. Spring-set plants in the frost-loosened accumulations at the base of the banks survived better than fall-set plants. Full cover from partial stands developed by spreading from rhizomes. This cover remained green most of the year. The succulent top growth that developed after fall rains was frequently killed back by low temperatures in winter; however, growth was resumed in spring. Some strains of crownvetch produced heavy seed yields, whereas others produced few seed. All plantings were free from disease, although one planting was damaged badly by aphids in early spring of 1960. Little is known of the range of adaptation of crownvetch across the Southland. It is not used as a forage; therefore, its use has been limited in the Southeast (figs. 14 and 15).

Figure 13.--A, When crownvetch and Abruzzi rye were seeded together on roadbank, the rye produced a good cover, protected the vetch against winter cold, and provided shade during the summer. B, One year after crownvetch-rye planting was photographed in A: Rye straw still provided a mulch for good stand of vetch.

Figure 14.--A general view of a long bank on which 15 different species were planted November 1956 and April 1957. Crownvetch, seeded in 1956 in rye straw mulch grown in place, is shown on the right.

Hairy and grandiflora vetches were mixed and seeded on a number of plots from 1957 to 1959, inclusive. Satisfactory stands and cover developed within 4 to 6 weeks from September and early October seedings. Usually the cover developed so rapidly and was so heavy that companion crops were crowded out. At maturity, the residue disintegrated quickly, leaving the plots without permanent protection. These two varieties bloomed freely but produced few seed.

Warm-Season Species

Of the perennial warm-season grasses, best results were obtained from common bermuda-grass and weeping lovegrass established from seed. Both species usually came up to good stands quickly and developed adequate cover within 4 to 6 weeks if they were planted from April 1 to June 15. Lovegrass germinated more quickly than bermuda, but it did not thicken as rapidly (fig. 16).

Figure 15.--Crownvetch plonts were spoced 3 by 3 feet in November 1956. Full cover wos obtoined by lote summer of 1958. Crownvetch hos ottroctive folioge and is beoutiful in full bloom.

Figure 16.--General view of Coostal bermudogross ond weeping lovegross growing on o low roodbonk. Both plants provide good cover in full stond. Lovegross is eosy to estoblish, owing to its ropid germinotion with limited moisture.

Coastal bermudagrass was used on a limited number of banks. It was planted by stolons spaced 3 by 3 feet. This adapted, vigorous, hybrid bermuda does not produce viable seed. After widely spaced plants became well rooted, they spread more rapidly than the seedling stands of common bermuda, covering their planted areas with the first season's growth. However, complete bank coverage was obtained somewhat more quickly with the common variety, since its initial stands were established by broadcast seeding. Several plantings of Northrup-King bermuda were made from seed. Northrup-King No. 37, a giant bermuda, was winterkilled badly. The bermudagrasses are not adapted to shady banks adjacent to forested areas.

Argentine, Pensacola, and Wilmington bahiagrasses germinated and developed more slowly than other grasses tested. Argentine bahia was winterkilled in this area. Wilmington bahia was most winter-hardy, followed closely by Pensacola. Although the bahiagrasses developed slowly, they withstood the high temperatures on southern exposures and unfavorable sites better than the other grasses tested.

Honeysuckle adapted well to steep banks. When spaced 3 by 3 feet over an entire bank and fertilized properly, good cover was produced in 2 years. Where it was planted in staggered rows at the bottom of the bank, spaced not over 3 by 3 feet, it was useful for holding frost-loosened material on the bank. In about 4 years, with good survival and adequate fertilizer treatments, these plants covered the entire bank. Honeysuckle was useful adjacent to wooded areas where sunlight was limited and competition from trees was heavy. Honeysuckle stands, developed from wild plants or from seed dropped by birds, have encroached on a number of the grass plantings (fig. 17).

Kudzu was excellent for covering long steep banks of considerable height and slope. A row at the top of the bank, with plants spaced approximately 3 by 3 feet, provided runners that trailed down and rooted on the face of the bank. A second row with like spacing planted near the base of the bank soon developed coverage that held the frost-loosened material. Once established, kudzu required no maintenance treatment. However, it spread into adjacent forest areas and damaged young timber.

Figure 17.--A cover of honeysuckle that developed from natural stands is smothering out bahiagrass plantings on a roadbank of moderate slope. Honeysuckle, a vine plant, is useful on steep rough areas.

Ornamentals including daylilies, iris, vinca, and English ivy were used adjacent to home sites and public areas. Daylilies and iris planted from rhizomes, spaced 3 by 3 feet over the bank, usually gave good cover in 2 years. When fully developed and in bloom, daylilies and iris made a very showy bank for a period of 6 to 8 weeks during the blooming season (fig. 18).

Vinca minor and English ivy, both small vines, were established in a similar manner. When these plants fully covered the bank, they formed a good protective cover but were not as ornamental as daylilies. Vinca survived more easily and grew more rapidly than ivy. Both vinca and ivy were badly damaged by sunscald, particularly on southern and western exposures.

Broomsedge, a native plant requiring little fertilizer, has proved successful on several roadbanks and has withstood the droughty conditions on southern exposures. Stands of this species were established by cutting the mature straw in old abandoned fields when seed were ripe in October and spreading it as a light mulch on unprepared and unfertilized banks. When seed began to germinate the following spring, fertilization preserved stands and an excellent cover developed. Although only a small amount is required, where fertilizer was omitted or delayed too long after germination, the weak plants failed because of starvation or were washed off the bank by summer rainstorms. On a number of old roadbanks, thin natural stands of broomsedge plants were fertilized to encourage growth and seed production. Cover developed by this method was effective, economical, and seemed to be rather permanent. Complete fertilizer (4-12-12) applied each year for 2 years at the rate of 500 pounds per acre and topdressed with 50 pounds of nitrogen per acre was adequate to develop good cover (figs. 19 and 20).

Sericea lespedeza, a perennial legume, was used to a limited extent. It was established by direct seeding and by mulching with its seed-bearing straw. Both methods of establishment were successful. Sericea survived well on unfavorable sites adjacent to forest where light was reduced and competition from tree roots was heavy. It was injured badly by late summer mowing. Sericea will not survive long in wet soils, but is adapted to most well-drained roadbank sites. It is widely used on steep rocky banks were it is extensive root system tends to hold soil in place (fig. 21).

Figure 18.--Closeup of daylilies grown for erosion control and beautification of highway bank.

Figure 19.--Fertilizer stimulated natural stands of native poor-land types of wild plants to grow and provide good cover. Plot at right was fertilized with 1 ton of 4-12-12 and 2 tons of lime per acre in early March 1958. Maintenance fertilizer was 500 pounds of 4-12-12 plus 50 pounds of N per acre each year in 1959 and 1960. Plot to the left was fertilized with 250 pounds of 4-12-12 and 2 tons of lime per acre in early March 1958. Maintenance fertilizer consisted of 250 pounds of 4-12-12 and 50 pounds of N per acre in 1959 and 1960. No additional seeding was done. Although the plot on the right was fertilized at a different rate from the plot on the left, the covers developed on the plots were approximately the same. Plot in center received neither fertilizer nor lime.

Use of Different Mulch Materials

During the summer large amounts of rain falling at high intensity were very destructive to new seedings of slowly developing species. The beating action of raindrops and runoff floated most of the fertilizer and many of the seed from the planted area. In extreme cases, plots were damaged by runoff from areas above some of the planted banks. Where fertilizer was lost, seedlings failed to develop until they were refertilized (figs. 22 and 23).

The use of mulch was beneficial for reducing weather hazards during the establishment period. Frost action was most destructive to fall-seeded, slow-developing legumes that were not mulched with straw. Seedlings on the face of the bank were often lifted up by spewfrost and broken off, and only a narrow row of plants were left near the bottom of the bank or in protected areas. Frequently, grass planted after November 1 and not mulched was killed by spewfrost in the germinating stage. In addition to immediate plant damage, frost action increased fertilizer losses from steep banks. Tables 7, 8, and 9 show the results of the mulch studies.

In general, most mulches improved seed germination, stands, and growth by conserving moisture; helped to anchor fertilizer and seed in place; and insulated against frost action. Mulch was more beneficial for the slowly developing, fall-seeded species than for the rapidly developing, spring-seeded grasses. It was needed more on slopes greater than 2 to 1 than on gentler slopes.

Figure 20.--Broamsedge straw, cut from adjacent field areas in October when full of mature seed, was lightly mulched on this roadbank. In May, after seeding and when stands were up, fertilizotion preserved the stand.

Figure 21.--Closeup of sericea used for erosion control on roadbank. Sericea, a deep-rooted perennial legume, provides excellent cover in full stand. This plant is adapted to most roadbank sites, but will not stand frequent late summer mowing.

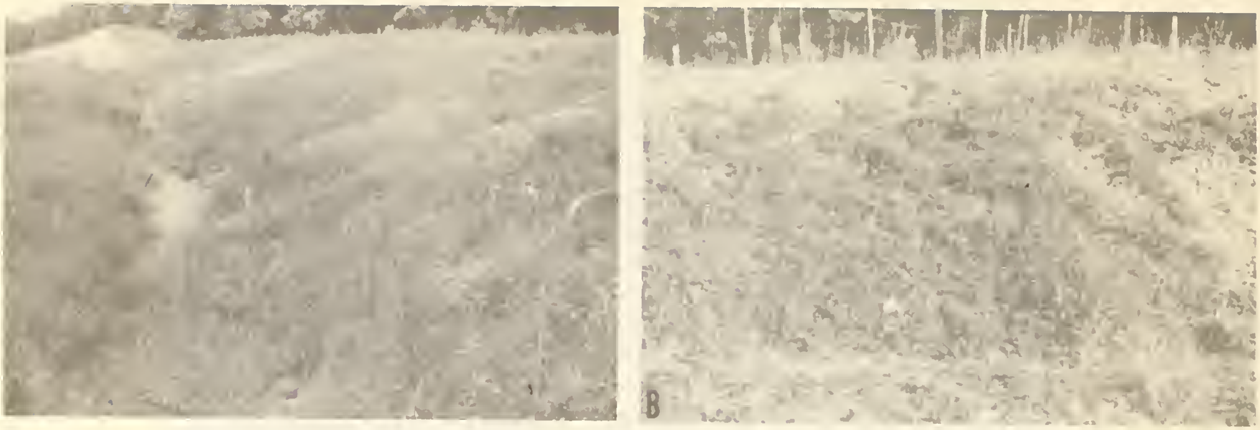

Figure 22.--A, General view of crownvetch, a cool-season legume, mulched with different materials. Mulch was essential to obtain stands and for the growth of slow-developing winter legumes. B, Crownvetch planted in October 1958 and mulched with grain straws. Note the fine stand and growth.

Figure 23.--This area was planted to crownvetch in October 1958. The area to the right of stakes was mulched with plastic sheets. The area to left of stakes was not mulched. Good stands developed over both plots, but plants were heaved out of the soil by frost action. Heavy summer rains destroyed stands developed from spring seeding where the bank was not mulched.

Table 10 gives a comparison of results obtained with various mulches. Crop straws, such as small grain and sericea, free from crabgrass and weeds, evenly spread at the rate of 1 to 2 tons per acre, were effective and reasonably economical to use.

Sawdust, applied in a thin layer on the surface of the soil, conditioned clay soils and aided seedling emergence. It did not possess cohesive properties like the straws and as a result most of it washed off the banks in runoff.

Pine straw was exceptionally good material for mulching experimental plots. It was free of grass and weed seed, remained in place well, and protected the plots against weather hazards (figs. 24, 25).

TABLE 7.--Summary of covers produced with different plant species by plantings made with and without mulch

Species	Sites	Mulch Treatment[1]	Cover ratings[2] U[3]	M[3]	L[3]	Average
	Number					
Fescuegrass	13	NM	7.9	8.2	8.5	8.2
Do	13	M	9.3	8.8	9.5	9.2
Orchardgrass	12	NM	7.6	7.2	7.7	7.5
Do	12	M	8.8	8.6	8.6	8.6
Bromegrass	11	NM	6.6	7.0	7.3	7.0
Do	11	M	8.2	7.7	8.4	8.1
Common bermudagrass	8	NM	7.3	8.3	8.7	8.1
Do	8	M	9.3	9.8	9.8	9.6
Coastal bermudagrass	4	NM	3.5	4.6	6.1	4.7
Do	4	M	7.3	8.9	9.1	8.5
Pensacola bahiagrass	8	NM	7.5	8.1	8.1	7.8
Do	8	M	8.7	9.4	9.2	9.1
Wilmington bahiagrass	8	NM	6.5	6.3	8.5	7.8
Do	8	M	9.3	9.3	9.3	9.3
Argentine bahiagrass	8	NM	7.2	7.8	7.7	7.6
Do	8	M	8.6	9.3	9.5	9.1
Lovegrass	8	NM	9.6	10.0	10.0	9.9
Do	8	M	9.9	10.0	10.0	10.0
Daylilies	5	NM	4.2	5.5	7.4	5.7
Do	5	M	6.4	7.5	8.4	7.4
Crownvetch	5	NM	3.1	6.1	8.1	5.7
Do	5	M	5.1	6.6	8.2	6.6
Vinca minor	4	NM	4.5	5.2	6.9	5.6
Do	4	M	6.0	7.7	8.7	7.5
Ivy	4	NM	4.3	7.5	8.8	6.9
Do	4	M	6.4	8.4	9.3	8.0
Rye	5	NM	5.7	4.8	6.1	5.5
Do	5	M	7.1	5.7	7.6	6.8
Ryegrass	5	NM	5.4	4.7	6.6	5.5
Do	5	M	6.9	6.7	6.9	6.8
Sericea lespedeza	2	NM	9.3	9.5	9.9	9.6
Do	2	M	9.3	9.9	10.0	9.7
Honeysuckle	5	NM	7.3	7.4	7.5	7.4
Do	5	M	9.0	8.9	8.9	8.9
Kudzu	1	NM	10.0	10.0	10.0	10.0
Do	1	M	10.0	10.0	10.0	10.0
Hairy vetch	5	NM	5.1	3.4	6.0	4.8
Do	5	M	6.6	5.4	7.5	6.5

[1] NM = no mulch; M = mulched.
[2] 0 = no cover; 10 = 100 percent coverage.
[3] U = upper third of bank; M = middle third of bank; L = lower third of bank.

Jute bagging was superior to all other mulches tested for controlling rill and sheet erosion in heavy rainstorms. It was best suited for use in flow channels and for protecting banks against water damage and floods. Jute bagging, an open weave material of 1/2- and 2-inch mesh, did not conserve moisture nor insulate against frost as well as did the crop straw mulches.

Clear, white, and yellow plastics were used for both spring-seeded and fall-seeded plant species. White and yellow plastics conserved moisture by reducing evaporation. Clear plastic not only conserved moisture but also increased surface moisture by condensation and increased the soil temperature, thus speeding germination. After stands developed, it was necessary to remove all plastic sheets to prevent sunscald and weak seedling development. Fall and spring stands of slowly developing legumes started under plastic appeared to be weakened and were

TABLE 8.--Cover developed by crownvetch, a slowly developing legume, which was planted with and without mulch on Cecil soil

Planting site no.	Date planted	Slope	Mulch treatment[1]	Cover ratings[2]			
				U[3]	M[3]	L[3]	Average
23	10/58	3:1	NM	1.7	0.7	4.2	2.2
23	10/58	3:1	M	2.3	2.4	5.6	3.4
23	3/59	3:1	NM	.4	2.0	2.4	1.6
23	3/59	3:1	M	3.1	3.8	5.0	3.9
36	9/59	2:1	NM	4.1	1.7	.9	2.2
36	9/59	2:1	M	5.8	4.6	4.2	4.9
36	3/60	2:1	NM	1.5	1.3	2.2	1.7
36	3/60	2:1	M	4.1	5.6	6.1	5.3
Average cover without mulch..........................				1.9	1.4	2.4	1.9
Average cover with mulch.............................				3.8	4.1	5.5	4.4

[1] NM = no mulch; M = mulched.
[2] Ratings were made by four individuals. 0 = no cover, 10 = 100 percent cover.
[3] U represents upper third of bank; M represents middle third of bank; L represents lower third of bank.

TABLE 9.--Cover developed by different grasses and legumes after heavy rainstorms on selected planting sites, with and without mulch

Planting site no.[1]	Date planted	Soil type	Slope	Species	Mulch treatment[2]	Cover ratings[3]			
						U[4]	M[4]	L[4]	Average
				Number					
21	9/58	Decatur	2:1	6	NM	6.8	6.5	8.0	7.1
21	9/58	do	2:1	6	M	8.5	7.6	8.7	8.2
22	9/58	do	1:1	6	NM	3.6	1.2	2.1	2.3
22	9/58	do	1:1	6	M	4.8	3.6	3.5	4.0
31	4/59	Cecil	3:1	7	NM	1.7	1.6	4.0	2.5
31	4/59	do	3:1	7	M	9.3	9.3	8.8	9.1
31	4/59	do	2:1	7	NM	5.1	6.4	6.1	5.9
31	4/59	do	2:1	7	M	7.8	8.8	8.8	8.5
Average cover from grasses with no mulch........................						4.3	3.9	5.0	4.4
Average cover from grasses with mulch...........................						7.6	7.3	7.4	7.4

[1] Grasses included in study: Nos. 21 and 22: Fescuegrass, orchardgrass, bromegrass, ryegrass, rye, and hairy vetch; No. 31: Lovegrass; common, Coastal, and N. K. 37 bermudagrasses; Wilmington, Pensacola, and Argentine bahiagrasses.
[2] M = Mulch; NM = no mulch.
[3] Ratings were made by four individuals. 0 = no cover; 10 = 100 percent cover.
[4] U represents upper third of bank; M represents middle third of bank; L represents lower third of bank.

lost because of frost in winter and rainstorms in summer. The plastic sheets were difficult to use because heavy weights were necessary to keep them in place.

Water-soluble latex, a rubberized material mixed with water and sprayed on the soil after seeding, looks good, particularly for grasses. However, only preliminary results are available at the present time. It formed a black plastic film on the surface of the soil that reduced evaporation, anchored seed and fertilizer against erosion, and increased temperature, which speeded up germination, in the case of bermudagrass. Water-soluble latex mulch was not so successful for spring-seeded crownvetch as it was for bermudagrass.

TABLE 10.--Percentage cover produced by three grasses and one legume planted and mulched with different mulch materials

Mulches[1]	Wilmington bahia, PS 1 and 5[2]	Common bermuda, PS 14,16,32[2]	Lovegrass, PS 17[2]	Crownvetch	
				Fall-planted	Spring-planted
	Percent	Percent	Percent	Percent	Percent
No mulch	68.0	86.0	55.0	2.5	30.0
Pine straw	74.0	98.0	100.0	75.0	70.0
Grain straw, 2 tons	....	98.0	100.0	80.0	75.0
Grain straw, 4 tons	....	98.0	100.0	80.0	90.0
Paper	82.0	....	94.0	....	....
Clear plastic	....	91.2	....	....	....
White plastic	....	83.0	....	10.0	30.0
Yellow plastic	....	78.0	....	....	....
Sawdust	....	83.3	100.0	69.0	55.0
Sericea lespedza straw	80.0	....	....	....	....
Jute	....	98.0	....	35.0	80.0
Water soluble latex	....	93.0	....	....	....
Grass mat	....	....	20.0	....	....

[1] See page 50 for description and rates of application.
[2] PS = planting site.

Figure 24.--A general view (in upper half of photograph) of roadside areas sown to common bermudagrass, with different plots mulched with pine straw, 2 and 4 tons per acre of grain straw, paper mesh, clear plastic and no mulch. Mulch was essential for anchoring seed and fertilizer on steep slopes and for protecting all slope conditions from heavy rainstorms. In general, the crop straws were more effective and easier to use.

Summary descriptions of the planting sites for vegetative studies are given in the appendix, table 12.

Figure 25.--The mature stand of bermudagrass resulting from the mulch treatments.

Mulch Grown in Place

Abruzzi rye, a fall-seeded, cool-season annual, was excellent for quick stabilization and for growing mulch in place. The seed were relatively large compared with those of other crops used. Being naked, the seed germinated quickly with limited moisture and grew vigorously when properly fertilized. When seeded together with crownvetch, the growing rye gave satisfactory protection to the vetch seedlings by reducing frost damage and conserving fertilizer. It also supplied shade in summer, which was helpful to the small plants. When mature, the rye straw was resistant to decay and remained effective against weather hazards for two or more years (fig. 13).

Browntop millet, a warm-season annual, was used in a similar manner as rye but for quick stabilization in summer. Millet is a smaller plant than rye, but it usually produced adequate mulch and cover grown in place in which to start permanent species. Mulching was not so essential for growing either rye or browntop millet as for most other seeded species.

Common Site Problems

Some limestone valley soils of the area, particularly Decatur, were very compact, making them difficult to prepare.

Steepness of slopes materially affected the treatment. On slopes greater than 2:1, the subsoil loosened during preparation rolled to the bottom of the bank. Even when mulched, seed and fertilizer frequently were lost from the steeper banks. Seedbeds on slopes less than 2:1 were much more easily prepared. Even without the use of mulch, in many cases cover was obtained very successfully with rapidly growing species.

To a greater degree, the sod-forming grasses and legumes were successful on friable soils and lower slopes, whereas the difficult soils and steeper, higher roadbank slopes were stabilized more easily with vine-type plants, which were planted near the bottom and at the top of the bank.

In forested and mountainous areas, competition from trees and excessive shade prevented the use of many species. Honeysuckle, sericea, and broomsedge showed considerable hardiness in such areas.

Low-grading plants like vinca minor and English ivy were badly injured by sunscald, particularly on slopes facing west or south. Damage was not so great on northern or eastern exposures.

Several hundred soil samples collected from roadbanks in the project area were analyzed for calcium, nitrogen, phosphorus, and potassium. All samples were moderately to highly acid with no nitrogen and only traces of phosphorus and potassium. It was necessary to add the three major nutrient elements in adequate amounts to grow satisfactory cover on roadbanks. Collection of soil samples and analysis after fertilizing and seeding revealed that much of the added fertilizer had been washed off, leached out, or used up, leaving the plants undernourished.

Nitrogen Evaluation Test on Bermudagrass

Where different rates of 8-24-8 fertilizer containing soluble and slowly water-soluble nitrogen were used, yields were increased progressively as the rate of fertilizer was increased. Of the two sources of nitrogen, water-soluble nitrogen gave higher bermuda hay yields than did the slowly water-soluble nitrogen for comparable rates of application. However, the October yields from the soluble nitrogen treatments were less than the July yields, indicating that most of the soluble nitrogen was exhausted. Results are shown in table 11.

Topdressing of fertilizer applications were made at the rate of 50 pounds per acre at intervals, as needed, to produce adequate cover. Ammonium nitrate and urea gave the greatest increase in yield of bermudagrass hay. Ureaform and 10-20-10 fertilizer with slowly water-soluble nitrogen failed to hold the October yield up to the July level (fig. 26, table 11).

TABLE 11.--Average yields of bermudagrass, July and October clippings, as a result of different rates of 8-24-8 with water-soluble and slowly water-soluble nitrogen

Treatment No.	Amount of fertilizer	Kind of fertilizer, 8-24-8	Total yield, July clippings	Total yield, October clippings	Total yields from both clippings
	lb./acre		lb./acre	lb./acre	lb./acre
1	625	Slowly soluble N.	1,938	512	2,450
2	1,250	....do	2,508	2,381	4,889
3	1,875	....do	2,846	6,578	9,424
4	2,500	....do	3,810	9,709	13,519
5	625	Soluble N	10,959	1,521	12,480
6	1,250	....do	15,556	4,608	20,164
7	1,875	....do	19,437	7,683	27,120
8[1]	625	....do	5,426	7,750	13,176
9[1]	625	....do	3,698	9,188	12,886
10[1]	625	....do	3,706	1,684	5,390
11[1]	625	....do	3,815	3,715	7,530

[1] Treatments 8 to 11, inclusive, were topdressed as needed: treatment 8, topdressed with 50 lb. of N from urea; treatment 9, topdressed with 50 lb. of N from ammonium nitrate; treatment 10, topdressed with 50 lb. of slowly soluble type N from ureaform; treatment 11, topdressed with 50 lb. of N from 10-20-10 slowly water-soluble nitrogen.

Figure 26.--In the nitrogen evaluation study, different rates of 8-24-8 containing water-soluble nitrogen were applied. Plot to the right was fertilized with 625 pounds of 8-24-8 per acre. No nitrogen was applied as a topdressing. Plot to the left was fertilized with 625 pounds of 8-24-8 and topdressed with 50 pounds of N derived from ammonium nitrate.

SUMMARY

Runoff and Erosion

Soil losses from four bare roadbank areas are reported for the July 1 to December 31, 1957, period, and for six plots for the January 1, 1958, to December 31, 1959, period. Each plot consisted of a bare cut roadbank and ditch with adjacent vegetated road shoulder, varying in size from 0.16 to 0.30 acre per total runoff area. The actual erodible areas, including only the roadbank section and ditch under measurement, ranged from 0.11 to 0.21 acre. The banks varied in height from 2 to 16 feet, with lengths of 206 to 365 feet. Heavy annual losses occurred on all six bare roadbanks, with losses ranging from 25 to 359 tons per acre.

Frost action, which occurred from the middle of December to about February 20, was a major factor in losses from most of the banks except for newly sloped, firm banks. Orientation of the roadbanks greatly influenced frost action and erosion. In addition, banks facing the northwest in this area received more direct beating action of rainstorms than banks facing southeast. Thus, all banks facing the northwest yielded twice as much soil loss as those facing the southeast.

Annual seasonal losses measured to date from roadside areas depended mainly on the rainfall pattern from March through July after the soil had been loosened on the banks by frost action. Once the loose soil had been washed from the banks, heavy losses from the firm hard banks did not occur again until the following spring. However, a heavy rainfall may wash large quantities of deposited soil from the flow channel at any time of the year.

Roadbank Covers

Twenty-eight different species and varieties were planted with and without mulch during the roadbank stabilization studies, which began in November 1956. Plantings were repeated annually until 1960.

Where possible, the soil was prepared and 1 ton of 4-12-12 and 2 tons of lime were worked into the soil with a chain harrow before seeding. Maintenance applications of 1,000 pounds of 4-12-12 and 50 pounds of N per acre were made annually just before the growing season.

To a great degree, the sod-forming grasses and legumes were successful on friable soils and lower slopes, whereas the difficult soils and steeper, higher roadbank slopes were stabilized more easily with vine-type plants that were planted near the bottom and at the top of the bank.

Excessive shade and competition from trees prevented the use of many species in forest and mountainous areas. However, honeysuckle, kudzu, sericea, and broomsedge showed considerable hardiness in such areas.

Daylilies grew well on all slopes and exposures. In this climate they bloomed for about 6 weeks through June and early July, and proved useful for adding beauty to areas adjacent to home sites and public areas.

Fescue was superior to other grasses for fall planting. It was vigorous and free from disease.

Abruzzi rye provided quick cover, produced mulch in place, and was a good nurse crop for slow-growing legumes.

Crownvetch was a promising cool-season, perennial legume, but required two or more years to develop cover whether seed or plants were used.

Common bermudagrass and lovegrass were the best perennial summer grasses.

Wilmington and Pensacola bahiagrasses produced good cover, but developed slowly.

Honeysuckle and kudzu were the best vine-type plants for rough areas. English ivy survived poorly and grew slowly.

Vinca minor was hardy and developed faster than English ivy. Both were injured by sunscald on southern and western exposures.

Sericea provided good cover in full stands, but was thinned by late summer mowing.

Broomsedge was cut when seed were mature, and a light mulch of it was made on unprepared banks. When the seed germinated the following spring, fertilizer stimulated the seedlings to full cover. Good cover was developed on a number of areas by fertilizing thin natural stands of broomsedge.

Mulches

Mulch was essential on steep slopes for slow-developing plants. Mulch anchored the seed and fertilizer in place, insulated the soil against frost damage, and reduced erosion. It was not so essential for rapidly developing plants on moderate slopes. In general, the crop straws applied at the rate of 1 to 2 tons per acre gave best results.

Soil Nutrients

The addition of adequate amounts of nitrogen, phosphorus, and potash was necessary to grow satisfactory cover on roadbanks. Analysis of soil samples after fertilizing and seeding revealed that much of the added fertilizer had been washed off, leached out, or used up, leaving the plants undernourished.

Plantings of common bermudagrass made in April 1959 were fertilized with different rates of 8-24-8 with water-soluble and slowly water-soluble nitrogen to determine the nitrogen effects on cover development. Where both water-soluble and slowly water-soluble nitrogen were applied, the cover and yeild of grass increased progressively from the lowest rate to the highest rate.

Amonium nitrate and urea applied as a topdressing at the rate of 50 pounds of N per acre gave greatest increase in growth of cover. Plots topdressed with ureaform and 10-20-10 containing slowly water-soluble nitrogen produced less cover than those fertilized with ammonium nitrate and urea. All treatments produced adequate cover to prevent serious erosion except in those plots that were fertilized at the minimum rate.

On roadbanks, in general, establishment of adequate cover requires fertilization and protection from weather hazards. Maintenance of such cover requires additional periodic fertilization.

APPENDIX

TABLE 12.--Summary description of the 40 planting sites for vegetative study at Cartersville, Ga., 1956-60

Plot no.[1]	Site conditions[2]	Plant species	Mulch	Cover rating[3]	Remarks[4]
1	Plantings made 11/8/56 on Decatur soil on 10- to 20-ft. bank, 1:1 slope; exposure, east.	No seed	None	5.6	
		....do	Pine straw	8.7	
		Orchardgrass	None	3.6	
		....do	Pine straw	3.7	
		Fescuegrass	None	5.9	
		....do	Pine straw	7.9	
		Bromegrass	None	2.9	
		....do	Pine straw	4.9	
		English ivy	None	9.3	Cover: volunteer native plants.
		....do	Pine straw	9.5	
		Honeysuckle	None	3.3	
		....do	Pine straw	6.5	
1	Plantings made 4/17/57 on Decatur soil on 10- to 20-ft. bank, 1:1 slope; exposure: east.	Wilmington bahiagrass	Pine straw	4.6	
		....do	Sericea	4.9	
		....do	Paper	3.3	
		....do	None	2.7	
		....do	....do	3.0	
2	Plantings made 11/4/56 on Cecil soil on 10- to 20-ft. bank, 1:1 slope; exposure, east.	Orchardgrass	None	7.9	
		....do	Pine straw	9.7	
		Honeysuckle	None	10.0	
		....do	Pine straw	10.0	
		Kudzu	None	10.0	
		....do	Pine straw	10.0	
		Fescuegrass	None	8.9	
		....do	Pine straw	10.0	
		Bromegrass	None	6.4	
		....do	Pine straw	9.9	
		English ivy	None	7.7	
		....do	Pine straw	8.3	
		Daylilies	None	8.8	
		....do	Pine straw	9.8	
		Crownvetch	None	10.0	
		....do	Pine straw	10.0	
2	Plantings made 4/1/57 on Cecil soil on 10- to 20-ft. bank, 1:1 slope; exposure, east.	Wilmington bahiagrass	None	7.3	
		....do	Pine straw	8.7	
		Argentine bahiagrass	None	9.3	
		....do	Pine straw	8.7	
		Pensacola bahiagrass	None	9.0	
		....do	Pine straw	9.0	
		Lovegrass	None	9.6	
		....do	Pine straw	10.0	
3	Plantings made 11/14/56 on Cecil soil on 10- to 20-ft. bank, 2:1 slope; exposure, south.	Honeysuckle	None	10.0	
		....do	Pine straw	10.0	
		English ivy	None	9.6	Cover: volunteer native plants.
		....do	Pine straw	9.2	
3	Plantings made 11/14/56 on Cecil soil on 10- to 20-ft. bank, 2:1 slope; exposure, north.	Honeysuckle	None	5.7	
		....do	Pine straw	9.9	
		English ivy	None	10.0	Cover: volunteer native plants.
		....do	Pine straw	10.0	
4	Plantings made 11/1/56 on Cecil soil on 10- to 20-ft. bank, 1:1 slope; exposure, south.	No seed	None	9.4	Cover: volunteer native plants.
		....do	Pine straw	9.6	
		Orchardgrass	None	9.6	
		....do	Pine straw	9.8	
		Fescuegrass	None	9.4	
		....do	Pine straw	9.6	
		Bromegrass	None	8.9	
		....do	Pine straw	8.8	
		Broomsedge	None	9.3	
		....do	Pine straw	9.1	

See footnotes at end of table.

TABLE 12.--Summary description of the 40 planting sites for vegetative study at Cartersville, Ga., 1956-60--Cont.

Plot no.[1]	Site conditions[2]	Plant species	Mulch	Cover rating[3]	Remarks[4]
4	Plantings made 4/1/57 on Cecil soil on 10- to 20-ft. bank, 1:1 slope; exposure, south.	Wilmington bahiagrass	None	6.9	
		....do	Pine straw	9.4	
		Pensacola bahiagrass	None	9.1	
		....do	Pine straw	8.7	
		Argentine bahiagrass	None	7.4	
		....do	Pine straw	7.7	
4	Plantings made 11/1/56 on Cecil soil on 20- to 30-ft. bank, 1:1 slope; exposure, north.	No seed	None	9.2	Cover: volunteer native plants.
		....do	Pine straw	9.8	
		Orchardgrass	None	9.7	
		....do	Pine straw	9.8	
		Fescuegrass	None	9.8	
		....do	Pine straw	10.0	
		Bromegrass	None	9.7	
		....do	Pine straw	10.0	
		Broomsedge	None	9.9	
		....do	Pine straw	10.0	
4	Plantings made 4/1/57 on Cecil soil on 20- to 30-ft. bank, 1:1 slope; exposure, north.	Wilmington bahiagrass	None	9.9	
		....do	Pine straw	9.8	
		Pensacola bahiagrass	None	9.8	
		....do	Pine straw	9.8	
		Argentine bahiagrass	None	9.8	
		....do	Pine straw	9.4	
5	Plantings made 4/19/57 on Cecil soil on 10- to 20-ft. bank, 2:1 slope; exposure, south.	Wilmington bahiagrass	Pine straw	9.8	Cover: largely volunteer fescue.
		....do	Sericea straw	9.8	
		....do	Paper	9.6	....do
		....do	None	9.7	....do
		....do	....do	9.7	....do
6	Planting made 4/28/57 on Cecil soil on 20- to 30-ft. bank, 3:1 slope; exposure, north.	No seed	None	9.9	Cover: volunteer native plants.
		....do	Pine straw	9.7	
		Wilmington bahiagrass	None	9.9	
		....do	Pine straw	10.0	
		Pensacola bahiagrass	None	10.0	
		....do	Pine straw	10.0	
		Argentine bahiagrass	None	10.0	
		....do	Pine straw	9.9	
		Common bermudagrass	None	9.8	
		....do	Pine straw	9.8	
		Sericea lespedeza	None	9.1	
		....do	Pine straw	9.4	
		Lovegrass	None	10.0	
		....do	Pine straw	10.0	
6	Planting made 4/28/57 on Cecil soil on 10- to 20-ft. bank, 3:1 slope; exposure, south.	No seed	None	9.1	Cover: volunteer native plants.
		....do	Pine straw	9.1	
		Kobe lespedeza	None	9.0	
		....do	Pine straw	8.9	
		Lovegrass	None	10.0	
		....do	Pine straw	10.0	
		Sericea lespedeza	None	10.0	
		....do	Pine straw	10.0	
		Common bermudagrass	None	9.6	
		....do	Pine straw	9.9	
		Argentine bahiagrass	None	9.6	Cover: largely volunteer honeysuckle.
		....do	Pine straw	9.8	
		Pensacola bahiagrass	None	9.8	
		....do	Pine straw	10.0	....do
		Wilmington bahiagrass	None	10.0	....do
		....do	Pine straw	9.9	....do
9	Planting made 4/18/57 on Cecil soil on 10- to 20-ft. bank, 1:1 slope; exposure, south.	Lovegrass	None	10.0	
		....do	Pine straw	10.0	
		Common bermudagrass	None	9.8	
		....do	Pine straw	9.9	

See footnotes at end of table.

TABLE 12.--Summary description of the 40 planting sites for vegetative study at Cartersville, Ga., 1956-60--Cont.

Plot no.[1]	Site conditions[2]	Plant species	Mulch	Cover rating[3]	Remarks[4]
9	Planting made 4/18/57 on Cecil soil on 10- to 20-ft. bank, 1:1 slope; exposure, north.	Lovegrass	None	10.0	
		....do	Pine straw	10.0	
		Common bermudagrass	None	10.0	
		....do	Pine straw	10.0	
		Argentine bahiagrass	None	9.6	Cover: largely native plants.
		....do	Pine straw	9.7	
10	Planting made 3/20/58 on Madison soil on 30- to 40-ft. bank, 3:1 slope; exposure, south.	Lovegrass	None	9.9	
		....do	Pine straw	10.0	
		Common bermudagrass	None	10.0	
		....do	Pine straw	9.9	
		Pensacola bahiagrass	None	9.7	
		....do	Pine straw	9.7	
		Argentine bahiagrass	None	9.6	
		....do	Pine straw	9.5	
		Wilmington bahiagrass	None	9.5	
		....do	Pine straw	9.6	
11	Planting made 9/6/57 on Cecil soil on 10- to 20-ft. bank, 2:1 slope; exposure, south.	Fescuegrass	None	9.6	
		....do	Pine straw	9.5	
		Orchardgrass	None	9.8	
		....do	Pine straw	9.3	
11	Planting made 9/6/57 on Cecil soil on 10- to 20-ft. bank, slope 2:1; exposure, north.	Fescuegrass	None	9.8	
		....do	Pine straw	10.0	
		Orchardgrass	None	9.9	
		....do	Pine straw	9.9	
		Bromegrass	None	9.9	
		....do	Pine straw	9.9	
12	Planting made 9/8/57 on Cecil soil on 20- to 30-ft. bank, 2:1 slope; exposure, north.	Fescuegrass	None	8.9	
		....do	Pine straw	10.0	
		Orchardgrass	None	6.2	
		....do	Pine straw	9.4	
		Bromegrass	None	5.3	
		....do	Pine straw	5.3	
		Fescuegrass	None	9.4	
		....do	Pine straw	8.6	
		No seed	None	5.8	Cover: volunteer native plants.
13	Planting made 9/28/57 on Cecil soil on 20- to 30-ft. bank, 1:1 slope; exposure, north.	Crownvetch	None	8.9	
		....do	Pine straw	7.4	
		Vinca minor	None	7.0	
		....do	Pine straw	9.4	
		English ivy	None	6.8	
		....do	Pine straw	7.1	
		Daylilies	None	7.2	
		....do	Pine straw	8.5	
13	Planting made 9/28/57 on Cecil soil on 20- to 30-ft. bank, 1:1 slope; exposure, south.	Crownvetch	None	4.5	
		....do	Pine straw	5.8	
		Vinca minor	None	6.7	
		....do	Pine straw	7.0	
		English ivy	None	6.7	
		....do	Pine straw	9.6	
		Daylilies	None	4.5	
		....do	Pine straw	7.7	
13	Planting made 9/29/57 on Cecil soil on 20- to 30-ft. bank, 1:1 slope; exposure, east.	Crownvetch	None	6.1	
		....do	Pine straw	7.2	
		Vinca minor	None	7.0	
		....do	Pine straw	7.1	
		English ivy	None	6.2	
		....do	Pine straw	7.1	
		Daylilies	None	5.3	
		....do	Pine straw	6.7	

See footnotes at end of table.

TABLE 12.--Summary description of the 40 planting sites for vegetative study at Cartersville, Ga., 1956-60--Cont.

Plot no.[1]	Site conditions[2]	Plant species	Mulch	Cover rating[3]	Remarks[4]
18	Treatment made 3/11/58 on Cecil soil on 20- to 30-ft. bank, 1:1 slope; exposure, north.	No seed	None	[5] 1.4	No fertilizer or lime treatment.
		....do	....do	[5] 4.8	250 lb./acre 4-12-12, plus 50 lb. N.[6]
		....do	....do	[5] 7.2	500 lb./acre 4-12-12, plus 50 lb. N.[6]
		....do	....do	[5] 5.5	1,000 lb./acre 4-12-12, plus 50 lb. N.[6]
		....do	....do	[5] 6.9	2,000 lb./acre 4-12-12, plus 50 lb. N.[6]
19	Plantings made 5/10/58 on Decatur soil on 30- to 40-ft. bank, 1:1 slope; exposure, west.	Coastal bermudagrass	None	4.2	
		....do	Grain straw	7.1	
20	Planting made 10/20/57 on Cecil soil on 20- to 30-ft. bank, 2:1 slope; exposure, south.	Broomsedge	None	10.0	Mulch seeded with broomsedge when seed were mature.
21	Plantings made 9/25/58 on Decatur soil on 20- to 30-ft. bank, 2:1 slope; exposure, east.	Fescuegrass	None	8.0	
		....do	Pine straw	9.5	
		No seed	None	6.1	
		Orchardgrass	....do	9.3	
		....do	Pine straw	9.2	
		No seed	None	8.9	
		Bromegrass	....do	8.7	
		....do	Pine straw	9.4	
		No seed	None	4.6	
		Abruzzi rye	....do	4.9	
		....do	Pine straw	6.3	
		No seed	None	2.6	
		Ryegrass	....do	6.9	
		....do	Pine straw	9.0	
		No seed	None	2.4	
		Hairy vetch	....do	5.0	
		....do	Pine straw	6.0	
		No seed	None	3.6	
22	Plantings made 9/25/58 on Decatur soil on 20- to 30-ft. bank, 1:1 slope; exposure, west.	Fescuegrass	None	2.5	Replicated site for comparison with site 21. Site 22 was severely damaged by rain due to heavy runoff from watershed above.
		....do	Pine straw	7.4	
		No seed	None	2.6	
		Orchardgrass	....do	2.7	
		....do	Pine straw	4.8	
		No seed	None	1.9	
		Bromegrass	....do	3.1	
		....do	Pine straw	5.0	
		No seed	None	2.0	
		Abruzzi rye	....do	1.9	
		....do	Pine straw	2.7	
		No seed	None	.7	
		Ryegrass	....do	1.8	
		....do	Pine straw	2.2	
		No seed	None	.8	
		Hairy vetch	....do	1.6	
		....do	Pine straw	1.7	
		No seed	None	.4	
23A	Plantings made 10/7/58 on Cecil soil, 20- to 30-ft. bank, 2:1 slope; exposure, west.	Crownvetch	None	2.2	
		....do	Pine straw	4.0	
		....do	2 tons/acre grain straw	4.6	
		....do	4 tons/acre grain straw	4.7	
		....do	Sawdust	2.4	
		....do	White plastic	1.4	
23B	Plantings made 3/2/59 on Cecil soil, 30- to 40-ft. bank, 2:1 slope; exposure, west.	Crownvetch	None	1.6	
		....do	Pine straw	5.6	
		....do	2 tons/acre grain straw	4.2	
		....do	4 tons/acre grain straw	5.6	
		....do	Sawdust	2.5	
		....do	White plastic	1.8	

See footnotes at end of table.

TABLE 12.--Summary description of the 40 planting sites for vegetative study at Cartersville, Ga., 1956-60--Cont.

Plot no.[1]	Site conditions[2]	Plant species	Mulch	Cover rating[3]	Remarks[4]
13	Plantings made 9/29/57 on Cecil soil on 20- to 30-ft. bank, 2:1 slope; exposure, east.	Fescuegrass	None	9.6	
		....do	Pine straw	9.9	
		No seed	None	6.4	Cover: volunteer native plants.
		Orchardgrass	....do	9.8	
		....do	Pine straw	9.7	
		No seed	None	6.7	Cover: volunteer native plants.
		Bromegrass	....do	9.2	
		....do	Pine straw	9.5	
		No seed	None	7.5	Cover: volunteer native plants.
		Abruzzi rye	....do	8.7	
		....do	Pine straw	8.7	
		No seed	None	7.3	Cover: volunteer native plants.
		Ryegrass	....do	5.3	
		....do	Pine straw	7.0	
		No seed	None	4.8	Cover: volunteer native plants.
		Hairy vetch	....do	6.5	
		....do	Pine straw	7.1	
		No seed	None	7.0	Cover: volunteer native plants.
14	Plantings made 4/1/58 on Cecil soil on 30- to 40-ft. bank, 3:1 slope; exposure, south.	Bermudagrass	None	10.0	
		....do	Pine straw	10.0	
		....do	2 tons/acre grain straw	10.0	
		....do	4 tons/acre grain straw	10.0	
		....do	Paper mesh	10.0	
		....do	Clear plastic	10.0	
16	Plantings made 4/3/58 on Cecil soil on 30- to 40-ft. bank, Cecil soil; exposure, north.	Bermudagrass	None	10.0	
		....do	Pine straw	10.0	
		....do	2 tons/acre grain straw	10.0	
		....do	4 tons/acre grain straw	10.0	
		....do	Paper mesh	10.0	
		....do	Sawdust	10.0	
17	Plantings made 5/8/58 on Fullerton soil on 20- to 30-ft. bank, 3:1 slope; exposure, west.	Lovegrass	None	8.2	
		....do	2 tons/acre grain straw	9.4	
		....do	4 tons/acre grain straw	9.5	
		....do	Pine straw	9.6	
		....do	Paper mesh	9.1	
		....do	Sawdust	9.7	
17	Plantings made 5/8/58 on Fullerton soil on 20- to 30-ft. bank, 3:1 slope; exposure, east.	Lovegrass	None	8.2	
		....do	2 tons/acre grain straw	9.8	
		....do	4 tons/acre grain straw	9.8	
		....do	Pine straw	9.8	
		....do	Paper mesh	9.2	
		....do	Sawdust	10.0	
17	Plantings made 5/8/58 on Fullerton soil on 20- to 30-ft. bank, 3:1 slope; exposure, west.	Coastal bermudagrass	None	9.1	
		....do	Pine straw	9.7	
18	Treatment made 3/11/58 on Cecil soil on 20- to 30-ft. bank, 1:1 slope; exposure, south.	No seed	None	[5] 1.6	No fertilizer or lime treatment.
		....do	....do	[5] 6.1	250 lb./acre 4-12-12, plus 50 lb. N.[6]
		....do	....do	[5] 7.1	500 lb./acre 4-12-12, plus 50 lb. N.[6]
		....do	....do	[5] 8.1	1,000 lb./acre 4-12-12, plus 50 lb. N.[6]
		....do	....do	[5] 8.4	2,000 lb./acre 4-12-12, plus 50 lb. N.[6]

See footnotes at end of table.

TABLE 12.--Summary description of the 40 planting sites for vegetative study at Cartersville, Ga., 1956-60--Cont.

Plot no.[1]	Site conditions[2]	Plant species	Mulch	Cover rating[3]	Remarks[4]
31	Plantings made 4/8/59 on Cecil soil on 20- to 30-ft. bank, 3:1 slope; exposure, north.	Lovegrass	None	10.0	Rainstorms immediately after planting washed seed and fertilizer from unmulched plots.
		....do	Pine straw	10.0	
		Coastal bermudagrass	None	1.4	
		....do	Pine straw	9.1	
		Common bermudagrass	None	1.5	
		....do	Pine straw	10.0	
		Northrup King 37 bermudagrass	None	3.5	
		....do	Pine straw	8.6	
		Pensacola bahiagrass	None	0	
		....do	Pine straw	6.4	
		Argentine bahiagrass	None	0	
		....do	Pine straw	10.0	
		Wilmington bahiagrass	None	.9	
		....do	Pine straw	9.8	
31	Plantings made 4/8/59 on Cecil soil on 20- to 30-ft. bank, 2:1 slope; exposure, north.	Lovegrass	None	9.5	Rainstorms immediately after seeding washed seed and fertilizer from unmulched plots.
		....do	Pine straw	9.8	
		Coastal bermudagrass	None	4.2	
		....do	Pine straw	7.9	
		Common bermudagrass	None	5.4	
		....do	Pine straw	8.8	
		Northrup King 37 bermudagrass	None	4.8	
		....do	Pine straw	7.8	
		Pensacola bahiagrass	None	5.4	
		....do	Pine straw	9.2	
		Argentine bahiagrass	None	4.7	
		....do	Pine straw	7.9	
		Wilmington bahiagrass	None	7.8	
		....do	Pine straw	7.2	
32	Plantings made 4/14/59 on Cecil soil on 20- to 30-ft. bank, 2:1 slope; exposure, south.	Common bermudagrass	None	4.1	Heavy rainstorm damaged plots soon after planting.
		....do	Pine straw	10.0	
		....do	2 tons/acre grain straw	9.9	
		....do	4 tons/acre grain straw	8.7	
		....do	Sawdust	9.0	
		....do	Clear plastic	5.6	
		....do	White plastic	6.4	
		....do	Yellow plastic	5.7	
		....do	Fine jute	7.7	
		....do	Coarse jute	7.5	
33	Planting made 4/28/59 on Cecil soil on flat bank.	Bermudagrass	None	---	Nitrogen evaluation study; four replications; cover variable due to rate and frequency of fertilizer applications.
35	Plantings made 9/16/59 on Decatur soil on 20- to 30-ft. bank, 2:1 slope; exposure, south.	No seed	None	3.9	Cover: volunteer native plants.
		Fescuegrass	....do	6.9	
		....do	Pine straw	9.5	
		No seed	None	2.5	Cover: volunteer native plants.
		Orchardgrass	....do	6.6	
		....do	Pine straw	9.8	
		No seed	None	1.5	Cover: volunteer native plants.
		Bromegrass	....do	4.8	
		....do	Pine straw	9.0	
		No seed	None	2.0	Cover: volunteer native plants.
		Hairy vetch	....do	5.9	
		....do	Pine straw	9.5	
		No seed	None	1.3	Cover: volunteer native plants.
		Abruzzi rye	....do	4.4	
		....do	Pine straw	8.2	
		No seed	None	.9	Cover: volunteer native plants.
		Ryegrass	....do	5.3	
		....do	Pine straw	6.9	

See footnotes at end of table.

TABLE 12.--Summary description of the 40 planting sites for vegetative study at Cartersville, Ga., 1956-60--Cont.

Plot no.[1]	Site conditions[2]	Plant species	Mulch	Cover rating[3]	Remarks[4]
35	Plantings made 9/16/59 on Decatur soil on 20- to 30-ft. bank, 2:1 slope; exposure, north.	Fescuegrass..........	None....................	5.8	
		....do...............	Pine straw.............	9.4	
		No seed..............	None....................	.3	Cover: volunteer native plants.
		Orchardgrass.........	....do..................	5.3	
		....do...............	Pine straw.............	8.4	
		No seed..............	None....................	.1	Cover: volunteer native plants
		Bromegrass...........	....do..................	6.1	
		....do...............	Pine straw.............	8.0	
		No seed..............	None....................	.2	Cover: volunteer native plants.
		Hairy vetch..........	....do..................	5.1	
		....do...............	Pine straw.............	8.1	
		No seed..............	None....................	1.2	Cover: volunteer native plants.
		Abruzzi rye..........	....do..................	7.6	
		....do...............	Pine straw.............	8.3	
		No seed..............	None....................	1.2	Cover: volunteer native plants.
		Ryegrass.............	....do..................	8.3	
		....do...............	Pine straw.............	9.1	
		No seed..............	None....................	1.0	Cover: volunteer native plants.
36A	Plantings made 9/17/59 on Cecil soil on 20- to 30-ft. bank, 2:1 slope; exposure, west.	Crownvetch...........	None....................	2.2	
		....do...............	Fine jute..............	2.3	
		....do...............	Coarse jute............	3.1	
		....do...............	Pine straw.............	5.6	
		....do...............	2 tons/acre grain straw	7.5	
		....do...............	4 tons/acre grain straw	8.9	
		....do...............	White plastic..........	2.3	
		....do...............	Sawdust................	4.3	
36B	Plantings made 10/10/59 on Cecil soil on 20- to 30-ft. bank, 3:1 slope; exposure, west.	Crownvetch...........	None....................	1.9	Transplantings
		....do...............	Pine straw.............	3.1	....do................
		Daylilies............	None....................	2.6	
		....do...............	Pine straw.............	4.4	
		Vinca minor..........	None....................	1.5	
		....do...............	Pine straw.............	6.4	
		Honeysuckle..........	None....................	1.3	
		....do...............	Pine straw.............	4.7	
		Broomsedge...........	None....................	7.3	
		....do...............	Pine straw.............	8.4	
36C	Plantings made 9/18/59 on Cecil soil on 20- to 30-ft. bank, 2:1 slope; exposure, west.	Crownvetch...........	None....................	3.4	
		....do...............	2 tons/acre grain straw	8.5	
		Crownvetch with 30 lb. of rye per acre	2 tons/acre grain straw	9.3	Rye was used as nurse crop for crownvetch.
		Crownvetch with 15 lb. rye per acre...	None....................	9.5	
		Crownvetch with 30 lb. rye per acre...	....do..................	9.2	
		Crownvetch with 60 lb. rye per acre...	....do..................	8.7	
36D	Plantings made 3/21/60 on Cecil soil on 40- to 50-ft. bank, 2:1 slope; exposure, west.	Crownvetch...........	None....................	1.7	
		....do...............	Pine straw.............	7.2	
		....do...............	2 tons/acre grain straw	7.4	
		....do...............	4 tons/acre grain straw	7.0	
		....do...............	Sawdust................	5.2	
		....do...............	White plastic..........	3.9	
		....do...............	Coarse jute............	3.9	
		....do...............	Water-soluble latex....	2.7	

See footnotes at end of table.

TABLE 12.--Summary description of the 40 planting sites for vegetative study at Cartersville, Ga., 1956-60--Cont.

Plot no.[1]	Site conditions[2]	Plant species	Mulch	Cover rating[3]	Remarks[4]
37	Plantings made 4/7/60 on Cecil soil on 20- to 30-ft. bank, 2:1 slope; exposure, west.	Common bermudagrass..	None...................	1.3	
		....do...............	Pine straw.............	3.0	
		....do...............	Sawdust................	.8	
		....do...............	2 tons/acre grain straw	2.6	
		....do...............	4 tons/acre grain straw	2.7	
		....do...............	Clear plastic..........	5.7	
		....do...............	White plastic..........	5.0	
		....do...............	Yellow plastic.........	3.5	
		....do...............	Jute...................	4.4	
		....do...............	Water-soluble latex....	3.6	
37	Plantings made 4/7/60 on Cecil soil on 20- to 30-ft. bank, 2:1 slope; exposure, west.	Common bermudagrass..	Water-soluble latex....	3.5	50 gal. per acre
		....do...............	....do.................	4.4	75 gal. per acre
		....do...............	....do.................	5.4	100 gal. per acre
		....do...............	....do.................	5.0	150 gal. per acre Water latex was diluted 1 gal. of stock solution to 7 gal. of water and used as spray.
40	Plantings made 10/5/60 on Cecil soil on 10- to 20-ft. bank, 4:1 slope; exposure, south.	Crownvetch and rye...	Pine straw.............	10.0	Fertilized with 500 lb./acre of 12-6-6.
		....do...............	....do.................	10.0	Fertilized with 1,000 lb./acre of 12-6-6.
		....do...............	....do.................	10.0	Fertilized with 1,500 lb./acre of 12-6-6.

[1] Sites 7 and 8 are small plantings which were not rated; site 15 is not planted; sites 24, 25, 26, 27, 28, and 29 are basal plantings which were not rated; sites 30, 38, and 39 are small plantings which were not rated.
[2] Bank distances refer to exposed face.
[3] 0 equal no cover, to 10 equal full protective cover. Ratings were made in June 1960.
[4] All plots limed with 2 tons per acre, except as noted.
[5] Cover was developed by native plants as result of fertilizer treatments.
[6] Annual maintenance fertilizer was 250 lb. 4-12-12 plus 50 lb. N to plots receiving 250 lb. initially. All other fertilized plots received 500 lb. 4-12-12 plus 50 lb. N per acre.

Errata sheet for ARS-41 Series Bulletin, "Control of Erosion in the Piedmont Uplands of Northwest Georgia."

Page 7. In table 2 under mulch for treatments for weeping lovegrass, "paper" should be "pine straw, 1 to 2 tons per acre".

Page 18. Under Figure 14 "Crownvetch seeded in 1956 - - -" should be "Crownvetch seeded in January 1959."

Page 27. In footnote 1 "See page 50 for description..." should be "See pages 7 and 8".

Page 29. In first line of first paragraph, "low-grading plants" should be "low-growing plants".

Pages 36 and 37 are reversed.